ORBITAL MACHINING APPARATUS

Background of the invention

1. Field of the invention

The invention generally relates to an orbital machining apparatus for producing a hole in a workpiece by means of a cutting tool rotating about its own tool axis as well as eccentrically (orbiting) about a principal axis corresponding to the longitudinal center axis of the hole to be machined. More particularly, the invention relates to an improved mechanism of said apparatus for transferring a rotational movement to an inner eccentric cylindrical body of a mechanism for adjusting the radial offset (orbit radius) of the cutting tool axis relative to the principal axis.

2. Description of the related art

WO 03/008136 A1 discloses an orbital machining apparatus for producing a hole in a workpiece by means of a cutting tool, said apparatus comprising:

a first actuator configured for rotating the cutting tool about its longitudinal center axis during the machining of the hole;

a second actuator configured for moving the cutting tool in an axial feed direction substantially parallel to said tool axis, said second actuator being simultaneously operable with said first actuator;

a third actuator configured for rotating the cutting tool about a principal axis, said principal axis being substantially parallel to said center axis of the tool and coaxial with a longitudinal center axis of the hole to be machined, said third actuator being simultaneously operable with said first and second actuators; and

a radial offset mechanism configured for controlling the radial distance of the center axis of the cutting tool from said principal axis, said radial offset mechanism comprising:

an inner cylindrical body having an eccentric cylindrical hole, said eccentric hole having a longitudinal center axis that is parallel to and radially offset from a longitudinal center axis of said inner body, said eccentric hole being configured to radially and rotatably support a spindle unit for operating said cutting tool; and

an outer cylindrical body having an eccentric cylindrical hole, said eccentric hole of said outer body having a longitudinal center axis that is parallel to and radially offset from a longitudinal center axis of said outer body, said inner cylindrical body being radially supported in said eccentric hole of the outer cylindrical body and rotatable therein so as to allow for adjustment of the radial distance of said center axis of the cutting tool from said principal axis, said third actuator including a first motor drivingly connected to the outer cylindrical body for individually rotating the latter about the longitudinal center axis thereof, and a second motor drivingly connected to the inner cylindrical body for individually rotating the latter about the longitudinal center axis thereof, said first and second motors being configured to rotate the outer and inner cylindrical bodies in synchronism to maintain a mutual rotary position thereof so as to keep the radial offset position of the cutting tool unchanged during a working operation.

The first and second motors are also configured to rotate the outer and inner cylindrical bodies in different angular speeds so as to vary the radial offset position of the cutting tool. Thus, two separate motors and the transmissions are configured for rotating the outer and inner cylindrical bodies either in synchronism (= no mutual rotation) during a working operation to maintain a predetermined mutual rotary position of the cylindrical bodies and thereby a predetermined radial offset (for making a cylindrical hole or recess in a workpiece), or in different angular speeds (mutual rotation) to vary the radial offset either during a working operation (e.g. for making a conical hole or recess) or during a non-working phase to adjust the radial offset to another desired radial offset value.

The transmission or mechanism for transferring a rotational movement from the second motor to the inner cylindrical body includes a coupling, which is configured for allowing the inner cylindrical body to perform an orbital movement about the principal axis while not rotating about its own center axis relative to the outer cylindrical body. The coupling also permits the inner cylindrical body to be rotated about its center axis relative to the outer cylindrical body by the second motor so as to vary the radial offset either during a working operation or during a non-working phase to adjust the radial offset to another desired radial offset value. This coupling comprises a fork-and-cam roller mechanism. A problem related to the fork-and-cam roller mechanism is that the contact surface of the cam roller wears with time and creates a play, which affects the degree of precision of the coupling mechanism and thus of the working process of the orbital machining apparatus.

Summary of the invention

An object of the present invention is to provide an orbital machining apparatus having a coupling arrangement, which eliminates the above mentioned drawbacks of the previous machines. For this purpose the apparatus comprises:

a first actuator configured for rotating the cutting tool about its longitudinal center axis during the machining of the hole;

a second actuator configured for moving the cutting tool in an axial feed direction substantially parallel to said tool axis, said second actuator being simultaneously operable with said first actuator;

a third actuator configured for rotating the cutting tool about a principal axis, said principal axis being substantially parallel to said center axis of the tool and coaxial with a longitudinal center axis of the hole to be machined, said third actuator being simultaneously operable with said first and second actuators; and

a radial offset mechanism configured for controlling the radial distance of the center axis of the cutting tool from said principal axis, said radial offset mechanism comprising:

an inner cylindrical body having an eccentric cylindrical hole, said eccentric hole having a longitudinal center axis that is parallel to and radially offset from a longitudinal center axis of said inner body, said eccentric hole being configured to radially and rotatably support a spindle unit for operating said cutting tool; and

an outer cylindrical body having an eccentric cylindrical hole, said eccentric hole of said outer body having a longitudinal center axis that is parallel to and radially offset from a longitudinal center axis of said outer body, said inner cylindrical body being radially supported in said eccentric hole of the outer cylindrical body and rotatable therein so as to allow for adjustment of the radial distance of said center axis of the cutting tool from said principal axis,

said third actuator including a first motor drivingly connected to the outer cylindrical body for individually rotating the latter about the longitudinal center axis thereof, and a second motor drivingly connected to the inner cylindrical body for individually rotating the latter about the longitudinal center axis thereof, said first and second motors being configured to rotate the outer and inner cylindrical bodies in synchronism to maintain a mutual rotary position thereof so as to keep the radial offset position of the cutting tool unchanged during a working operation, and the first and second motors being further configured to rotate the cylindrical bodies relative to each other so as to vary the radial offset position of the cutting tool, the third actuator further including a first rotating drive element coaxial to the outer cylindrical body and driven by the first motor, and a second rotating drive element coaxial to the outer cylindrical body and rotated by the second motor. According to the invention the second drive element is rotatably connected to a carrier ring by means of two diametrically opposed, radial drive pins such that the carrier ring may perform a radial sliding movement along the longitudinal axis of the drive pins relative to the second drive element while being rotated thereby, the carrier ring being connected to the inner cylindrical body by means of two diametrically opposed, radial carrier guide shafts, which are circumferentially spaced 90° from the drive pins, such that the inner cylindrical body may perform a radial sliding movement relative to the carrier ring while being rotated thereby.

Further details of the apparatus of the present invention will be clear from the following detailed description of a preferred embodiment thereof with reference to the accompanying drawings.

Brief description of the drawings

Fig. 1 is a schematic side sectional view of a previously known orbital machining apparatus having many components in common with the apparatus of the invention;

Fig. 2 is a side view of an orbital machining apparatus of the present invention;

Fig. 3 is a perspective view of the orbital machining apparatus of the invention;

Fig. 4 is an enlarged perspective view of a coupling arrangement for rotating an inner cylindrical eccentric body of the apparatus;

Fig. 5 is an end view of the coupling arrangement in Fig. 4; and

Fig. 6 is a perspective view from behind of the apparatus of the invention.

Detailed description of a preferred embodiment

As shown in Fig. 1, a conventional orbital machining apparatus 10 generally includes a spindle motor unit 12 that rotates a cutting tool 14 about its own axis 16, a radial offset mechanism 18, an eccentric rotation mechanism 20 and an axial feed mechanism 21. The apparatus 10 may be slideably mounted to a stationary stand 22 or mounted to a movable member, such as a robot arm (not shown). The axial feed mechanism 21 includes a stationary motor M which drives a ball screw 23a engaging a ball nut 23b fixedly secured to a machine housing H.

As shown in Fig. 1, the radial offset mechanism 18 basically comprises an inner hollow cylindrical body 24 rotatably supporting the spindle motor unit 12 therein. The spindle motor unit 12 is rotatably supported in an eccentric cylindrical hole 26 of the inner cylindrical body 24 via a fixation sleeve 28 and bearings 29. The eccentric hole 26 has a longitudinal center axis that is parallel to but radially offset a distance from the longitudinal center axis of the inner cylindrical body 24.

The eccentric inner cylindrical body 24 is, in its turn, rotatably supported within an axially extending eccentric hole 34 of a second, outer hollow cylindrical body 36. The eccentric hole 34 has a longitudinal center axis that is parallel to but radially offset a distance from the center axis of the outer cylindrical body 36 (the principal axis). Preferably, the holes 26 and 34 of the cylindrical bodies 24 and 36 have the same eccentricity, i.e. the hole center axes are radially offset the same distance from the respective center axis of the bodies 24 and 36. By rotating the inner cylindrical body 24 within the eccentric hole 34 of the outer cylindrical body 36, or by a mutual, relative rotation of the cylindrical bodies 24 and 36, it is thus possible to locate the center axis of the eccentric hole 26 of the inner cylindrical body 24 such that it, and hence the spindle motor unit 12 and the center axis 16 of the cutting tool 14, will coincide with the center axis of the outer cylindrical body 36. In this case there is no radial offset at all of the cutting tool axis 16. By performing a mutual, relative rotation of 180° of the inner and outer cylindrical bodies 24 and 36 away from this zero radial offset position, a maximum offset of the cutting tool axis 16 is obtained.

Basically, the outer cylindrical body 36 is rotatably supported in the housing H of the apparatus10 and is rotatable by a motor (not shown) via a belt 46, which engages a belt wheel 48 connected to the outer body 36. Likewise, the inner cylindrical body 24 is rotatable by a further motor via a belt 52, which engages a belt wheel 54 connected to the inner body 24 via a coupling 55 comprising a fork-and-cam roller mechanism. The belt wheel 54 is arranged to rotate in a concentric position relative

to the belt wheel 48. The coupling 55 is configured for allowing the inner cylindrical body 24 to perform an orbital movement about the principal axis while not rotating about its own center axis relative to the outer cylindrical body 36. This coupling 55 also permits the inner cylindrical body 24 to be rotated about its center axis relative to the outer cylindrical body 36 by said further motor so as to vary the radial offset either during a working operation or during a non-working phase to adjust the radial offset to another desired radial offset value.

As shown in Figs. 2-5, the present invention provides a new coupling 56 for rotating the inner cylindrical body 24 relative to the outer cylindrical body 36. The same reference numerals are used here for components corresponding to those in Fig. 1. The belt wheel 54, which is driven by a motor 50 and the belt 52, is connected to a drive element 57 in shape of a yoke having two diametrically opposed, axially extending lugs 58. A flat carrier ring 60 is located radially inside of the lugs 58 and is connected to and rotated by the drive element 57 by means of two diametrically opposed, radial drive pins 62 which extend inwardly from the lugs 58 and are slidably mounted in diametrically opposed sleeves 59 fixated to the carrier ring 60 such that the carrier ring 60 may perform a radial sliding movement along the longitudinal axis of the drive pins 62 relative to the drive element 57 while being rotated thereby. Furthermore, two diametrically opposed, radial carrier guide shafts 64, which are circumferentially spaced 90° from the drive pins 62, connect the carrier ring 60 and the inner cylindrical body 24 such that the latter may perform a radial sliding movement along the longitudinal axis of the guide shafts 64 relative to the carrier ring 60 while being rotated thereby. The drive pins 62 and the guide shafts 64 are snugly received in respective linear bearings 66 located in the carrier ring 60.

When the belt wheels 48 and 54 are rotated with the same angular speed during a working operation, the cylindrical bodies 36, 24 are rotated in synchronism by their respective motors 44, 50 and belts 46, 52. This means that no change of the radial offset value of the tool axis 16 will occur. In combination with an axial feed of the

cutting tool 14 into the workpiece (not shown) a cylindrical hole or recess may then be formed therein.

If the inner and outer cylinder bodies 24 and 36 are caused to perform a relative rotation by rotating the belt wheels 54 and 48 in different angular speeds, the radial offset value of the cutting tool axis 16 will be changed. This will make it possible to form a conical or tapered hole or a conical or curved section or recess in the workpiece when combined with an axial feed of the cutting tool 14 into the workpiece. The adjustment of the radial offset may also be done during a non-working phase or during a stop of the axial feed of the cutting tool.